TOWARDS BIOGAS UTILIZATION IN A DEPRESSED ECONOMY

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ABSTRACT

The production and application of biogas is documented. Biogas is a product of anaerobic fermentation of organic wastes and consists of methane, carbon dioxide, hydrogen sulphide, and other gases. Biogas can be used for lighting, source of heat for cooking and warming the house. Stationary engines, cars and trucks hitherto running on diesel and petrol can be converted to run successfully on biogas either wholly or in combination with diesel and petrol respectively. The digested sludge and slurry from biogas digester are also useful as manure, for algae production, and as feed material for fish, pig etc. Biogas can also be used as a veritable means of controlling pollution as well as for conservation and developments purposes. Governments are advised to create awareness on the production and utilization of biogas to fully utilize the benefit derivable from that aspect of renewable energy technologies (RET).

Keywords; *Biogas, digester, fermentation, fuel, sludge, utilization.*

1.0 INTRODUCTION

Biogas is a product of microbiological degradation processes. It is a gaseous mixture of methane, carbon dioxide, hydrogen sulphide and several other gases, produced by anaerobic fermentation of organic materials such as animal and human manure, leaves, twigs, grasses, industrial waste, etc. The presence of methane in biogas lends it the property of combustion which makes it suitable for cooking, lighting and powering prime movers (Mazumda, 1982). For many years, biogas was considered a waste product of anaerobic sludge digestion systems, and was simply flared off to prevent injury to personnel. In fact, some plants converted to aerobic digestion systems to eliminate this and other problems associated with anaerobic sludge disposal systems. At covered landfills, biogas was a nuisance which would simply migrate out of the ground. Many landfills installed peripheral gas collection systems and flares to burn the gas and prevent injury to personnel as well as the surrounding community (James et al, 1988, Awogbemi and Adeyemo, 2013).

One of the earliest to mention biogas was Van Helmont in 1630, in a communication about an inflammable gas emanating from decaying organic matter, but the energy crisis initiated by the 1973 Arab oil embargo brought a new awareness of the use of renewable fuels, including biogas. Subsequently, a number of projects sponsored by the U. S. Department of Energy (USDOE), other governmental funding agencies, and private industries, evaluated the use of anaerobic treatment systems for the production of energy. In addition, private enterprises have successfully recovered biogas from more than 200 landfills for production of thermal or electric energy (Maramba, 1978, James et al, 1988).

Biogas has gained prominence in the last decades in most serious developed and developing countries that are committed to developing their renewable source of energy particularly in the face of the ongoing energy crisis. For example, In 1999 Sweden has developed a national standard for biogas as vehicle fuel on request of the Swedish vehicle manufacturers as a design basis for fuel- and engine systems. Germany, Iceland, Netherlands, Austria, etc have over a decade ago been injecting biogas into their gas grid, while France, Japan, Sweden, Spain, Norway, etc now use biogas as vehicle fuel. In fact at the end of 2005 there were more than 5 million Natural Gas Vehicles (NGVs) powered by biogas in the world (Persson et al, 2006, Chawla, 1986).

2.0 PRODUCTION OF BIOGAS

Biogas is produced in a digester. A digester is a tank of many forms of design and construction methods, but generally, it should be airtight not only to prevent the escape of the biogas it produces but also to prevent the entrance of air since the biogas-producing bacterial thrive only in the absence of oxygen, the pressure inside the digester should no go below atmospheric pressure so as to prevent air entering the digester and mixing with biogas to form an explosive, it should be waterproof, and there should be sufficient headspace over the digester slurry so that the scum that forms on the surface of the slurry will not clog the gas outlet at the top of the digester. Also digesters are always provided with stirrers to mix the slurry and break the scum that forms on top of the slurry (Maramba, 1978). A digester may be classified according to its charging methods. The batch-fed digester is charged with fresh slurry to full capacity and sealed and the slurry is allowed to decompose for the duration of the retention time adopted, after which it is opened, the sludge discharged and the digester refilled. The continuous-fed digester is charged fully at the start of the operation and a small amount of fresh slurry is added either daily or weekly.

Generally the conditions for biogas production are (Maramba, 1978, Awogbemi and Adeyemo, 2013, Mazumda, 1982, and Adeyemo, 2003)

(i) Presence of the right kind of bacteria which should be in the active growing stage, and in sufficient numbers;

(ii) Presence of the raw materials well dispersed in water;

(iii) Adequate amounts of nutrients for the growth of the bacteria, particularly a carbon-to-nitrogen ratio of 30 to 1 or thereabouts;

(iv) Absence of air and of oxygen sources which means strict anaerobic conditions;

(v) pH of about 7 to 8 and a temperature range of 25oC to 37oC for mesophilic digestion;

(vi) Retention time sufficient to produce the maximum amount of biogas economically;

(vii) As the digester slurry decomposes, a mixture of coarse fibrous materials is released and accumulates at the surface, forming what is known as scum. If he scum is not broken it will prevent the biogas from surfacing.

Biogas comprises primarily methane (50-75%), carbon dioxide (25-50%), Nitrogen (0-10%), Hydrogen Sulphide (0-3%), Oxygen (0-2%), and Hydrogen (0-1%) Biogas consists of other element apart from methane; some of these constituents have an undesirable effect on final use of Biogas. For effective use of biogas, the gas has to be purified. For example, CO2 does not help in combustion process but reduce the calorific value of biogas. H2S is in minor quantity but it has corrosive action on combustion chamber and also reduces calorific value of biogas. Also traces of moisture are to be removed to ensure better thermal efficiency (Chawla, 1986).

Pure methane has a calorific value of 9,100kcal/m3 at 15.5°C and 1 atmosphere; the calorific value of biogas varies from 4,800 - 6,900 kcal/m3. In terms of energy equivalents, 1.33 - 1.87, and 1.5 - 2.1 m3 of biogas are equivalent to one litre of gasoline and diesel fuel, respectively. Biogas has an approximate specific gravity of 0.86 (www.gtz.de).

3.0 USES OF BIOGAS

There are various viable options for the utilization of biogas. These options can be categorized under five main sub-headings namely;

3.1 DOMESTIC USE

The primary domestic uses of biogas are body warming, cooking and lighting. Biogas can be used directly as a source of heat for body warming during winter. Because biogas has different properties from other commonly used gases, such as propane and butane, and is only available at low pressures (4 - 8cm water), stoves capable of burning biogas efficiently are specially designed. Lighting can be provided by means of a gas mantle, or by generating electricity. A typical family of six uses approximately 2.9 m^3/day of biogas. Biogas consumption for various domestic uses is as shown in table 1.

Table 1. Biogas consumption for various purposes.

Application	Specification	Consumption (m^3/hr)
Cooking/person/day		0.336-0.42
Lighting		0.28
Gas Engine		0.448-0.504
Generating Electricity/kwhr		0.616
Gas Stove	5cm diameter burner	0.322
	10cm diameter burner	0.462
	15cm diameter burner	0.63
Gas Lighting	1 mantle Lamp	0.07-0.084
	2 mantle Lamp	0.14
	3 mantle Lamp	0.168
Refrigerator	45cm x 45cm x 360cm	0.042-0.056
Boiling Water		0.28/gallon

Source: Mazundar, 1982

The fact that biogas has found wide utilization domestically is not unconnected with the fact that it can be replaced by most known fuels used for domestic purposes. For example 1m^3 of biogas can replace 0.52litre of diesel, 0.8litre of gasoline, 0.62litre of kerosene, 0.6litre of crude oil, 1.4kg of charcoal, 4.7kwh of electricity, 3.47kg of fire wood, etc.

In Nigeria, utilization of biogas at the domestic level has been limited to cooking using a locally fabricated stove. In such cases, digesters are built at the back of the kitchen and a flexible hose connects the gasholder with the stove. A valve is however provided to lock and unlock the hose as the need arises. In this case, the CO_2 is still present as impurity in the biogas. This, however, helps to prevent excessive burning of the gas. Biogas burns with a blue flame without soot or odour and since it is not stored under pressure like Liquefied Petroleum Gas; the risk of explosion is minimized.

3.2 AGRICULTURAL USES

The need to produce enough food for the ever growing population has engaged the attention of agricultural researchers in recent years. The development of chemical fertilizers brought some relieve until researches showed the adverse effects of food grown on chemical fertilizers on human health. Also continuous use of chemical fertilizers can deplete the soil of some nutrients, cause water pollution, and increase in the unused farm wastes (Maramba, 1978). Attention are now been shifted to use of natural fertilizers.

Digested sludge

Most solids not converted into methane settle out in the digester as a liquid sludge. Depending on the materials used and the conditions of digestion, this sludge contains many elements essential to plant life. Some of the elements are nitrogen, phosphorous, potassium plus small amounts of salts (trace elements), indispensable for plant growth such as boron, calcium, copper, iron, magnesium sulphur, zinc, etc.

Digested sludge as fertilizer.

Digested sludge contains nitrogen, which is considered particularly important because of its vital role in plant nutrition and growth, mainly in the form of ammonium (NH_4) whereas nitrogen in aerobic organic wastes is mostly in oxidized form (nitrates, nitrites). Increasing evidence suggests that for many land and water plants, ammonium may be more valuable as a nitrogen source than oxidized nitrogen in the soil as it is much less apt to leach away and more apt to become fixed to exchange particles (clay and humus).

Sludge, like all compost materials, adds humus and supports microbiological activity in the ground, increasing porosity of the soil and water-holding properties, all of which add up to increased crops. Unlike chemical fertilizers which are effective for a period of one year only, sludge is effective for a period of 3 years.

The sludge may be used as fertilizer in (i) Liquid form. In this form the slurry can be taken in buckets and put on vegetable gardens and around fruit trees, and (ii) Diluted form. The slurry is carried by irrigation water to fields and it is important to spread it all over the fields and not allow it to accumulate at one spot.

However, in using sludge as fertilizer, it must be noted that fresh digested sludge, especially from manures, has high ammonia content, and it may act like a chemical fertilizer by forcing a large dose of nitrogen on the plant and thus increasing the accumulation of toxic nitrogen compounds. To prevent this, it is best to let sludge age for a couple of weeks in the open or in a closed container for a few months before using it on the crops. The fresher it is the more it should be diluted with water before application.

Also, the continued use of digested sludge in any one area tends to make the soil acidic. To prevent this a little dolomite or limestone should be added at regular intervals to the sludge plots, allowing at least 2 weeks interval between applications to avoid excess nitrogen loss. As limestone tends to evaporate ammonia, a temporary nitrogen loss may be experienced when it is applied on the sludge plots.

Most vegetable crops such as potatoes, tomatoes, carrots, onions, garlic, etc, fruit tree such as orange, grape, apple, guava, mango, etc., and crops such as sugarcane, rice etc. are found to respond well to the use of digested sludge as fertilizer. However crops like wheat, cotton, etc. are found to be less responsive (Maramba , 1978, Mazumdar, 1982). In other to overcome the problem of conveying the sludge to the field, the digested slurry could be pumped into tankers and carried to the spot where it is required.

Slurry utilization.

Slurry is a form of liquid biofertilizer. Liquid biofertilizer contains only small amounts of nitrogen, phosphorus and potassium, but considering the fact that a large amount of water is needed for irrigation, these nutrients can build up to excessive quantities. Moreover, the liquid biofertilizers promotes a profuse growth of nitrogen-fixing algae wherever it is applied. Since algae have a short lie cycle, the decaying algae supplement the available nitrogen. Like the solid biofertilizer, the liquid sludge also carries trace elements like zinc, iron, manganese, copper and others.

Slurry can also be used as compost, in this case, the slurry, being full of bacteria which break down vegetable matter very well, is an excellent composting material (Mazumdar, 1982).

Sludge as feed material.

The sludge from a biogas plant is a good source of animal feed materials. It has been discovered that animals utilize only about half the nutrients in the feed that they consume. The animal manure still contains a considerable amount of undigested organic matter. This undigested material can be used again as feed. In fact, poultry and pig manure have been used as feed for pigs and cattle.

However, the use of fresh manure directly as feed is not commonly practiced. Many poultry and livestock raisers are understandably reluctant to feed it to their animals. They are either afraid of spreading diseases among their herd, or they may find the manure too messy to handle, or the idea of feeding it to their animals may grate against their sensibilities.

The solids are recovered from the sludge by allowing them to settle out in settling tanks and by draining the liquid. They are then dried, preferably under the sun. The dried lumpy solids are then ground and detoxified before mixing with the other feed materials. In small operations where wet feeding is practiced, the settled sludge may be fed with the slops without drying.

The objectionable characteristics of manure can be eliminated by processing it in a biogas plant. The aerobic pathogens or disease-carrying germs are killed in the anaerobic process. The sludge is not messy. Dry sludge looks and handles like humus. It is no longer has the offensive smell of manure, and unlike manure, it does not attract flies. Moreover, the biogas process not only retains the nutrients but it also enriches the sludge with B-complex vitamins, particularly vitamin B_{12}, which are synthesized during the biogas digestion. The use of dried sludge as pollard replacement in hog feeds brings about a lot of savings in feed cast and makes the pigs to reach the slaughter weight faster (Sathianathan, 1975, Maramba , 1978).

Algae production.

After the solids are recovered from the sludge, the remaining liquid, which contains nutrients and trace materials, is considered to be a good promoter of algae. Chlorella, a single-celled high protein (36-40% protein content) can be harvested with the liquid portion of the sludge in a shallow pond lined with concrete, metal or plastic material to avoid contamination and to make harvesting easier. Chlorella can be used in the amounts up to 10% of animal feeds to replace soyabean soil meal for protein supplementation (Sathianathan, 1975) .

3.3 BIOGAS AS FUEL

At present, the major fuels for Internal Combustion Engines are Gasoline, Diesel, Alcohol, Solar, Producer gas, LPG, Electricity and Hydrogen (Gupta et al, 1996). But some of these fuels have obvious limitations that necessitated research into the use of Biogas in Internal Combustion engines. For example, Gasoline contains many impurities. It has low octane number. All petroleum fuels oxidize slowly in presence of air. It has high cost. Alcohol has higher latent heat of vaporization and reduced charge temperatures before combustion, but suffers disadvantages of water absorption, corrosive and lubricant incompatibility. Liquefied Petroleum Gas reduces volumetric efficiency due to its high heat of vaporization. It is very corrosive. Response to blending is very poor. It has higher cost of transportation. It has higher cost for conversion kit. Electricity car has very heavy and low lifespan battery. Cost of replacing these batteries is high (Chawla, 1986).

Two types of engines can be run either wholly or partially on biogas:

· Four-stroke diesel engines

· Four-stroke spark-ignition engines

Four-stroke diesel engines:

A diesel engine draws air and compresses it at a ratio of 17:1 under a pressure of approximately 30-40 bar and a temperature of about 700°C. The injected fuel charge ignites itself. Power output is controlled by varying the injected amount of fuel, i.e. the air intake remains constant (so-called mixture control).

Four-stroke spark-ignition engines:

A spark-ignition engine (gasoline engine) draws a mixture of fuel (gasoline or gas) and the required amount of combustion air. The charge is ignited by a spark plug at a comparably low compression ratio of between 8:1 and 12:1. Power control is effected by varying the mixture intake via a throttle (so-called charge control). Four-stroke diesel and spark-ignition engines are available in standard versions with power ratings ranging from 1 kW to more than 100 kW.

Biogas engines are generally suitable for powering vehicles like tractors and light-duty trucks (pickups, vans). The fuel is contained in 200-bar steel cylinders (e.g. welding-gas cylinders) (www.gtz.de).

Converting diesel engines:

Diesel engines are designed for continuous operation (10000 or more operating hours). Basically, they are well-suited for conversion to biogas utilization according to either of two methods:

In the dual fuel approach the diesel engine remains extensively unmodified, except for the addition of a gas/air mixing chamber on the air-intake manifold (the air filter can be used as a mixing chamber). The injected diesel fuel still ignites itself, while the amount injected is automatically reduced by the speed governor, depending on how much biogas is injected into the mixing chamber. The biogas supply is controlled by hand. The maximum biogas intake must be kept below the point at which the engine begins to stutter. If that happens, the governor gets too much biogas and has turned down the diesel intake to an extent that ignition is no longer steady.

Normally, 15-20% diesel is sufficient. As much as 80% of the diesel fuel can thus be replaced by biogas. Any lower share of biogas can also be used, since the governor automatically compensates with more diesel.

As a rule, dual-fuel diesel performs just as well as comparable engines operating on pure diesel. As in normal diesel operation, the speed is controlled by an accelerator lever, and load control is normally effected by hand, i.e. by adjusting the biogas valve (keeping in mind the maximum acceptable biogas intake level). In case of frequent power changes at steady speed, the biogas intake should be somewhat reduced to let the governor decrease the diesel intake without transgressing the minimum diesel intake. Thus, the speed is kept constant, even in case of power fluctuations (www.gtz.de).

While special T-pieces or mixing chambers with a volume of 50 to 100% of the engine cylinder volume can serve as the diesel / biogas mixing chamber, a proper mixing chamber offers the advantage of more thorough mixing (Klaus, 1988).

Converting spark-ignition engines:

Converting a spark-ignition engine for biogas fueling requires replacement of the gasoline carburettor with a mixing valve (pressure-controlled venturi type or with throttle). The spark ignition principle is retained, but should be advanced as necessary to account for slower combustion (approx. 5°-10° crankshaft angle) and to avoid overheating of the exhaust valve while precluding loss of energy due to still-combustible exhaust gases. The engine speed should be limited to 3000 rpm for the same reason (Ehsan and Naznin, 2005). As in the case of diesel-engine conversion, a simple mixing chamber should normally suffice for continuous operation at a steady speed. In addition, however, the mixing chamber should be equipped with a hand operated air-side control valve for use in adjusting the air/fuel ratio (optimal "actual air volume/stoichiometric air volume" = 1.1) (Muhammad and Atan, 2012, Jose, et al, 2013).

Converting a spark-ignition engines result in a loss of performance amounting to as much as 30%. While partial compensation can be achieved by raising the compression ratio to E=11- 12, such a measure also increases the mechanical and thermal load on the engine. Spark ignition engines that are not explicitly marketed as suitable for running on gas or unleaded gasoline may suffer added wear & tear due to the absence of lead lubrication. The speed control of converted spark-ignition engines is effected by way of a hand-operated throttle. Automatic speed control for different load conditions requires the addition of an electronic control device for the throttle (www.gtz.de, Pankhaniya, et al, 2011).

3.4 BIOGAS AS POLLUTION CONTROL.

The large volume of animal manure, sewage and other organic wastes that are being produced daily all over the world makes pollution control a matter of great urgency. Improper disposal of theses wastes pollutes the air with offensive-smelling gases and poses a hazard to health. In water, the biodegradation of these organic wastes depletes the dissolved oxygen, sometimes rendering the water unfit for fish and other aquatic life (Maramba, 1978).

A number of ways have been devised to control such environmental pollution. The early approach consisted simply in treating the pollutants to remove the undesirable characteristics. Various systems with varying degrees of success in containing pollution have been generally used. Recent developments have come up with a better approach to pollution control. Pollution is now avoided by making use of the waste, and by turning the waste materials into something useful through waste recycling (Arthur, 2005).

The control of both air pollution and water pollution is achieved through the biogas works, which consists of the biogas plant and sludge-conditioning plant. The sludge-conditioning plant solves the water pollution problem by recovering and processing the sludge solids into animal feed materials while aerating and aging the remaining liquid in lagoons for use as fertilizer-irrigation water.

Pollution control tests carried out to check the effectiveness of biogas works. Samples are obtained and characterized at different points in the process, starting from the untreated waste to the point where it is discharged. The effluents are always analyzed by using the standards methods recommended by the American Public Health Association APHA (1971). The result of the tests, according to Maramba, 1978, showed (1) the reduction of chemical oxygen demand (COD), biochemical oxygen demand (BOD), total solids, suspended solids, dissolved solids, and threshold odor number; (2) maintenance of pH at 6.5-8.5; and (3) optimizing the dissolved oxygen content.

3.5 BIOGAS FOR CONSERVATION AND DEVELOPMENT.

Conservation

The conversion of waste materials into fertilizer and biogas helps protect the environment in five principal ways:

i. The generated biogas can replace traditional energy sources like firewood and animal dung, thus contributing to combat deforestation and soil depletion.

ii. Biogas can contribute to replace fossil fuels, thus reducing the emission of greenhouse gases and other harmful emissions.

iii. By tapping biogas in a biogas plant and using it as a source of energy, harmful effects of methane on the biosphere are reduced.

iv. By keeping waste material and dung in a confined space, surface and groundwater contamination as well as toxic effects on human populations can be minimized.

v. By conversion of waste materials and dung into a more convenient and high-value fertilizer ('biogas slurry'), organic matter is more readily available for agricultural purposes, thus protecting soils from depletion and erosion (Arthur, 2005, www.gtz.de).

Development

Farmers, industrial estates, municipalities and governments have diverging concepts of development. They can use biogas technology in different ways to contribute to their own development objectives.

Farmers may want to substitute inputs such as fertilizers, household and engine fuels by biogas slurry and the biogas itself. A biogas system can relieve farmers from work that they have formerly spent on dung disposal or dung application on their fields. By using biogas for cooking, lighting and heating, life quality for the whole family can improve. Improved stables, if they are part of the biogas system, can increase the output of animal husbandry. Improved farmyard manure may raise the yields of plant production.

Industrial estates can, by processing their waste in a biogas plant, fulfill legal obligations of waste disposal. They can, at the same time, generate energy for production processes, lighting or heating.

Municipalities can use biogas technology to solve problems in public waste disposal and waste water treatment. The energy output of biogas digestion is usually not a priority, but may respond to public energy demands such as street lighting, water pumping and cooking in hospitals or schools.

Governments have macro-economic interests that may render biogas technology an interesting option in overall development plans. On a national scale, a substantial number of working biogas systems will help reduce deforestation, increase agricultural production, raise employment, and substitute imports of fossil fuels and fertilizers. If macro-economic benefits are obvious and quantifiable, a government may even consider subsidizing biogas systems to bridge a micro-economic profitability gap (Arthur, 2005).

Craftsmen, engineers and maintenance workers have long been overlooked as a target group for biogas promotion. Not only does biogas technology open market niches for masons, plumbers, engineers and agronomists, they are often the most effective promoters of biogas technology.

4.0 CONCLUSION.

Biogas has been found to be very useful as a fuel for both stationary engines and cars and lorries, source of heat for cooking and warming, lighting, animal feeds, pollution control measures and for conservation and development purposes. The current spate of militancy and kidnapping in the oil-rich Niger-Delta, environmental effect of extracting crude oil, the effect of greenhouse effects are enough reasons to start looking for a viable alternative to oil. Without any doubt, biogas technology is a sure alternative.

Up till now, very little has been done in Nigeria to fully take the advantage of biogas technology, the state of our economy now offer us a rare opportunity to begin to explore biogas technology for the benefit of Nigerians. We should learn from countries like England, United States, China, Philippine, Japan, etc who has benefited immensely from biogas technology. Biogas, if well harnessed and utilized, can provide succor to the impoverished rural populace and improve their living standard. The multiply effect of this can make the economy to improve to the benefit of all.

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